The Mozan/Urkesh Archaeological Project: an Integrated Approach of Spatial Technologies

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Abstract. Urkesh, today a small village known as Tell Mozan, was a major political and religious center of the Hurrians – an elusive population of the ancient Near East. Archaeological excavations have shown that they had developed a strong urban civilization, at the very dawn of history, some 5000 years ago. A temple dominated the ancient skyline, at the top of a built-up terrace that rivaled the nearby mountains. A large royal palace, currently under excavation, has yielded written evidence that has allowed us to identify the ancient city. The excavation of Urkesh at Tell Mozan started in 1984 and through the year 2002 there have been 15 seasons of excavation. Excavations are carried out under a permit from, and with the collaboration of the Directorate General of Antiquities and Museums, the Ministry of Culture, the Syrian Arab Republic, the expedition is under the aegis of IIMAS - the International Institute for Mesopotamian Area Studies.

In this context, in 2003, an international collaboration between IIMAS and CNR-ITABC is started in order to use, during the fieldwork, 2d and 3d integrated technologies of archaeological survey: DGPS with Racal system, PDA, GIS mapping, remote sensing and 3D photomodeling. All these portable technologies address the archaeological excavations and intrasite surveys towards a complete digital mapping, 2d at the beginning of the acquisition and 3D in the final processing. In fact the use of DGPS with the Racal satellite correction allows an accuracy of 25-30 cm in real time (without post processing); in this way it is possible to create a GIS while spatial data are acquired and to plan geo-links with the archaeological layers. In the same time the use of photomodeling techniques has permitted, through calibrated sequences of digital photos, to construct 3d detailed photogrammetric models of the main archaeological structures, in order to geo-link these spatial data with a GIS background (already during the fieldwork).

Therefore, in the next, we could imagine to create a real time spatial information system during the fieldwork, so that it is possible to map digitally all the archaeological contexts (Uss, artifacts, structures, etc.) in geographic coordinates and, finally, to reconstruct a complete archaeological landscape

1 Introduction

The site of Tell Mozan is situated in the Syrian Jezireh, between the modern towns of Amouda and Qamishli. Work there is being done by a team from the International Institute for Mesopotamian Area Studies (IIMAS), under the auspices of the Syrian Department of Antiquities. The first excavation at the site began in 1984, while work on the Palace area (AA) began in 1990. The earliest structures at the site date to the Early Dynastic period (in areas C2, Oh1, Oa4 and Ob1), while the latest date to Mittani (A17 and A18).

In 2003 the collaboration between IIMAS and CNR-ITABC started in order to apply an integrated approach to the use of digital technologies for the reconstruction of the archaeological landscape and the topographic survey of the site.

2 Notes on Geography and History[1]

The importance of Urkesh is based on the presence of two socio-political groups: the Hurrians and the Akkadian empire. We know through inscriptions on seal impressions that the ancient name of Tell Mozan was Urkesh (Buccellati, G. 1998). Urkesh is a name evoked in later Hurrian texts describing the seat of the head of the Hurrian pantheon, Kumarbi, much as Mount Olympus was for the Greek pantheon. This city was considered by some, before our excavations, a fictitious birthplace for the religious world that the Hurrians had developed. Many aspects of the Hurrian religion survive to this day only through its incorporation in the Hittite belief system, which absorbed many of the Hurrian rituals and prayers (in part even retaining the Hurrian language, which would not have been understood by the vast majority of worshipers). The discovery of the seal impression of Tupkish (fig 1) naming him 'endan' or ruler of Urkesh undeniably ties the modern tell of Mozan to this ancient capital, and gives us the opportunity to explore the material culture tied to the religious structure evidenced in these later texts.

The most impressive example of the Hurrian presence at Urkesh is a monumental underground structure (A12; fig 2) (Kelly-Buccellati, M. 2002). It has been interpreted as a necromantic subterranean area for contacting the dead for oracular responses. A structure like this is completely alien to the Mesopotamian heartland, both in architecture as well as function, but is known by the Hurrian word abi which occurs in later texts. The rituals performed in this chamber are described in Hittite texts, and echoes of them are found in the Bible.

[1] This article arose through the collaboration between the Mozan/Urkesh Archaeological Project and the CNR-ITABC in the person of Maurizio Forte, whom I wish to thank especially for organizing this workshop and his personal encouragement. I also wish to thank the directors of the Mozan/Urkesh Archaeological Project for the opportunity to present these conclusions, which are not my own but due in great part to the directors as well as the staff who have worked at the site over the years. I retain here in part the discursive style of the presentation.

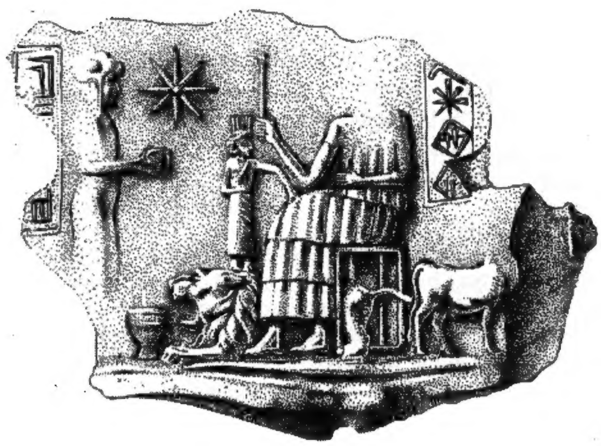

Fig. 1 A seal of Tupkish, king of Urkesh (about 2250 B.C.)

The first empire in the region is the empire of Akkad, but Urkesh (like Elam) remained independent due to its power base in the mountainous North (Buccellati, G. 1999). Seal impressions of the daughter of Naram-Sin, Taram-Agade, indicate an interaction between Urkesh and the Akkadians. Other sites in the area have material from the Akkadians, most notably Tell Brak, which was conquered and occupied by the troops of Naram-Sin. Material found at Tell Mozan, however, seems to indicate a different fate from that of Brak. The palace of king Tupkish, in use immediately before the Akkadian arrival in Mozan, shows no signs of destruction, which would be expected after an Akkadian siege, while the presence of a daughter of Naram-Sin seems to indicate an alliance through marriage.

The seal impression of Taram-Agade is of particular importance in Mozan due to its iconography, context and use (Buccellati, G. and M. Kelly-Buccellati 2002). The animal combat scene on the seal is characteristic of an Akkadian royal person, a scene whose use was carefully controlled by the royal court. The inscription mentions both Naram-Sin as the father of the seal bearer and the city of Agade as a part of her name. The clay sealings with the impression of Taram-Agade's seal were found in a cache in a level of the palace that, chronologically, immediately follows the period when Tupkish inhabited the palace. Between these two phases (2 and 3) there is no evidence of destruction of any kind, which would be expected if the Akkadian military forces had successfully attacked the city. In the same cache as the impressions of Taram-Agade a seal impression of a man named Unap was found; the seal showed signs of having been recut (Buccellati, G. and M. Kelly-Buccellati 2001). This is significant because impressions of the first version of the seal were found in the levels corresponding to the period of Tupkish, giving a clear chronological relationship between the two and showing some level of continuation in administrative personnel between the two periods. The fact that the seal was used to impress clay on doors is also significant, excluding the possibility that the seal impressions came from containers that had been shipped by Taram-Agade to Urkesh, which would have allowed for the possibility that she had not been present at Urkesh at all.

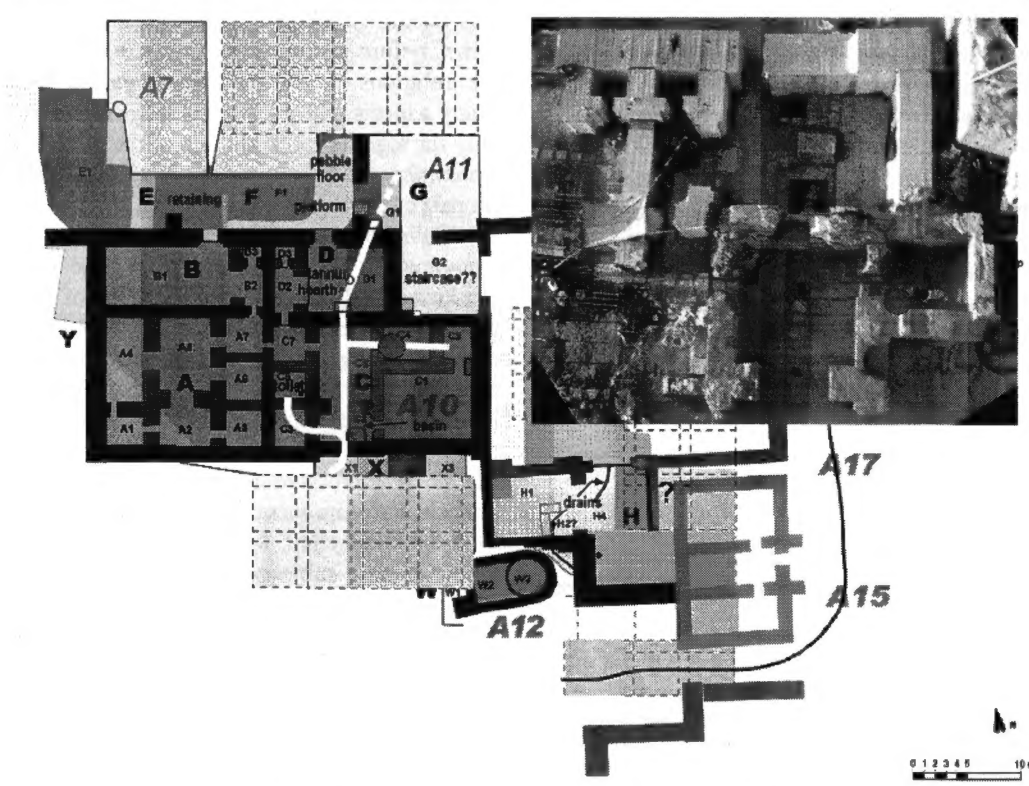

Fig. 2 General plan of the Royal Palace AP N 826 gh

3 Conservation of the Royal Palace

The major drive of the excavations since 1990 has been to uncover the palace of Tupkish, lying under three later periods of occupation. These later layers pose the problem of the conservation of the walls, since they require excavation and documentation while parts of the palace lay already uncovered to the elements. The first walls discovered date back to 1990, and we estimate that at least half of the palace remains under later layers that we are currently excavating. Originally the walls would have been protected by the roof of the palace, but direct exposure to the elements would cause their complete collapse within a few years.

The system developed at Tell Mozan to conserve the walls reflects three concerns (Buccellati, G. and S. Bonetti 2003). First, we wanted to protect the walls from the elements, ranging from snow and wind in the winter to temperatures over 50 degrees in the summer. Second, we wanted to preserve the walls as they were originally found; to 'rebuild' the walls with mud brick would partly preserve, but would also permanently hide the ancient material as we had found it. Third, we wanted the conservation to give a sense of the building as an organic whole, show the palace as a 'space' rather than merely an artifact.

The system developed (fig 3) consists of a metal substructure or latticework on legs that is shaped to reflect the width and length of the wall to be protected. The structure is then covered by a tarp which has been waterproofed and colored to reflect the different functional zones of the palace.

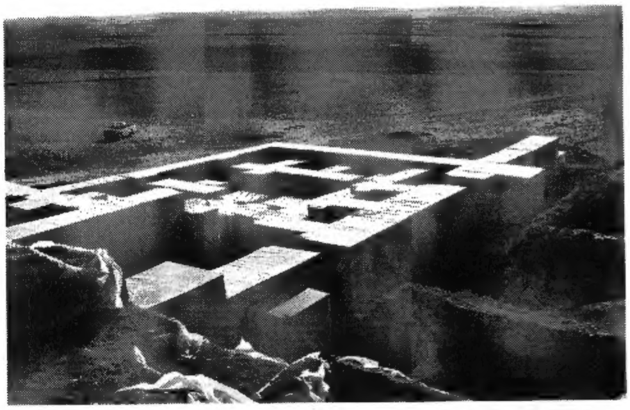

Fig. 3 Structure of conservation used to preserve the Royal Palace

This system offers many advantages. The metal structure holds the tarp away from the walls themselves, so that we avoid contact between the tarp and the walls, which would damage the walls and damage the tarp, especially during rain and ice storms. The tarp protects the walls from the direct rain and wind, while still letting them dry when the weather clears. The system can grow as the palace is dug, since each wall is covered independently of the others. This allows for the immediate protection of the walls as they are uncovered, instead of waiting to cover the entire building at the end of excavations, when the damage has already been done. If one is interested in seeing just the original walls, a crew of workmen can remove all the tarps and metal framework over the entire palace in about two days. The success of the system can be seen in the condition of the walls currently covered: some of these mud brick walls were excavated in 1994, but show only minor damage after ten years.

4 Objects from the Royal Palace: standard analysis

In counterpoint to the second part of this paper, I wish to briefly describe a standard approach to the documentation of objects in their context. In order to do justice to both the artifact as such and its context as part of a larger stratigraphic whole, one tends to publish a catalog of objects out of context with references to stratigraphic units, but with indices of objects organized by location or period.

In a presentation such as this, we can offer the photograph of an object, for example a clay tablet, which we then describe as an object. After the description as an artifact we can then bring in a plan of the building in which it was found, perhaps with a thumbnail of the tablet in the room from which it came. In this way we unify through the juxtaposition of two visuals the two aspects that define the object: its meaning as artifact and its meaning as part of a whole.

This approach is effective, but still leaves a lot of room for improvement. One of the results of the work of Maurizio Forte and Nicolo' Dell'Unto has been a more integrated way to incorporate these two aspects into a unified vision. This will be presented later on in the second section of this paper.

Fig. 4 A floor plan on a clay tablet from about 2300 B.C.

One clay tablet found in the 2003 season was very auspicious for our collaboration in mapping and modeling (fig 4) (Buccellati, G. 2004). This clay tablet was left accidentally for us by some ancient colleague: colleagues because here too, we have mapping. This architectural work plan represents a suite of 3 rooms, which could very well reflect an area sketch for the construction of a part of the palace, something that the architect might give a work crew.

4.1 The Urban Landscape

The city of Urkesh is very large by 3rd millennium standards – ½ sq. mile or 130 hectares, almost twice the size of Ebla. Several important elements of the urban landscape have been discovered, allowing for a broader understanding of the city as a whole as opposed to a collection of isolated excavation areas.

Around the outer city is a rise identified in a geological survey as an ancient city wall. This rise can still be seen clearly today, creating a moat effect in winter. Around the upper city is a second city wall, which had however already lost its defensive function by the time of the construction of the palace.

The upper city has two prominent buildings: the palace AP to the west and the temple BA to the east. These two do not stand in isolation, but rather both border a large, empty plaza that linked the two symbols of power in the city during the time of Tupkish.

The temple sits on an artificial hill which served to make it the highest building on the whole site, dominating the plaza below and visible from approaches to the city (Dohmann-Pfälzner, H. and P. Pfälzner 2002; Buccellati, G. 2004). This oval hill is evident in both the results of a geophysical survey as well as a GPS micro-relief done by Maurizio Forte (fig.5).

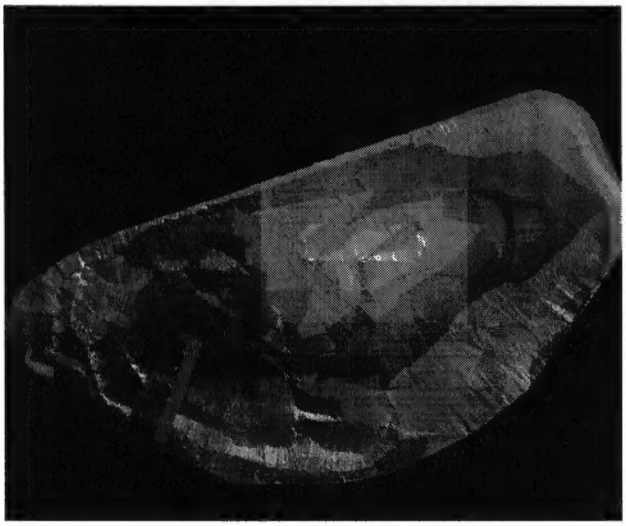

Fig. 5 DEM made by DGPS in real time and in kinematic way

Excavations have shown this hill to be an oval lined with stone accessed by a monumental stone staircase in the south.

The palace has next to it the abi structure, which was mentioned above in relation to Hurrian architecture. This Hurrian religious structure is a keyhole shaped construction that extends 8 meters below ground and is lined with massive stone blocks. When seen together with the raised temple in the background it emphasizes the vertical dimension of the two structures: the one high above the plain looking to the gods and the other cutting deep into the earth, approaching the world of the dead.

We have, then, a palace with a monumental abi ajoining it, a temple, a 40m wide plaza linking the two and two large city walls surrounding the city. This whole builds an organic urban monumental complex.

5 A Browser Edition

The aim of our project with regard to publication or data dissemination is an HTML interface accessible through the web and independently on a DVD. The advantages and disadvantages of publishing on the internet are well known and throughly discussed elsewhere. It is however worth underlining that our system has incorporated the functionality of hypertext in a type of relational database, useable only in digital format. The distribution of a DVD is fundamental because it provides a fixed bibliographical refrence for the data.

What is important about how we collect data is that the source is always an ASCII file – the dumbest, least technological file format available. But precisely because of its simplicity we hope it will survive the problems inherent in technological innovation. All of us have probably had files that we could not read immediately because they were saved in an older format, and perhaps still remember programs that were the standard of the moment but have ceased to be supported at all (Wordstar, Dbase).

Our system relies on notes written in a structured format which is then run through a program that merges all the files and sorts them by referent, giving a global file for each stratigraphic unit or object as output. In this way, notes taken by different members of the field team, the photographer, curator and conservator are all merged into a single file that contains all the documentation relating to a certain item or stratigraphic unit.

Both the input and the output of our process of data elaboration are in ASCII format, with the exception of images, for which the bitmap images are converted into JPG format, while vector format files are saved in WMF format. JPG and WMF seem to be the most ubiquitous format for bitmap and vector files, and to use a different

format would mean an unacceptable loss of image quality.

On top of our final 'product' we place a program that converts the ASCII into HTML. These HTML files resolve the codes we use in the ASCII files, automatically create the hyperlinks between different stratigraphic units as well as the objects found within them, create indices and insert the images as hyperlinked thumbnails. This is however a piggyback program – all the data remains in ASCII and JPG formats, so that as HTML dies, we loose all the work put into creating this program – but none of the data. A new program can be written to put our data into XML format or whatever is desired, and no information is lost.

We are not able to take advantage of some of the functionality of more advanced software by following this low-tech approach but since, as archaeologists, we destroy what we find, it is imperative that our data be as complete as possible, but also as permanent and accessible as possible. In a field where a book that is twenty years old is still considered relevant (even 60 years as with the Diyala or 100 as is the case with Nippur), to rely on a certain computer format is dangerous. Twenty years ago a company named Intel had just come out with the first of a new line of computer processors called the 8086, a company named Microsoft came into being and, in the first year at Tell Mozan, we began using the first laptop, the Tandy 100. The exponential growth of technology is impressive, but the fact that no physical media format that existed in 1984 still exists in computers today is disconcerting; for example, the Tandy 100 used a cassette drive, CP/Ms used 8" drives and 5¼" drives were the newest on the market, and were also the last floppies to actually be 'floppy'. Apart from the problem of media, no file written in 1984 can be read by a modern computer with the exception of ASCII-based files.

We have a choice between using a computer as a super-word processor, publishing in paper format and limiting electronic publishing to PDF format files, and thereby insuring the durability of data in a paper copy. Or else the other option allows us to exploit the power of computers, especially in referential databases, but then we must take into account the short life-span of the files created. The system at Mozan speaks to the problem of durability by using the ASCII format, while exploiting the possibility of referentiality by using hypertext in the HTML format.

6 An integrated Approach towards the digital Technologies: the virtual Heritage

We define "virtual heritage" the digital information derived by perception, interpretation, learning, knowledge, communication of a cultural item (object, site, monument, territory, landscape); therefore the virtual heritage is an ontology of the cultural heritage. It is the whole, the context, the more than each single part; we could say that virtual heritage represents more than a physical item, because it is constituted of a world of information and it multiplies the possibilities of knowledge through any kind of interaction (simulation, communication, immersion, queries, and exchange).

In the nineties the concept of virtual heritage was born: virtual heritage represents the way in which we acquire digital information concerning the cultural heritage, so that to have a significant increasing of content/context of data through cognition, perception, education, reticular learning (through virtual reality systems and digital archives). In this scenario a multidisciplinary and interdisciplinary approach is needed, whether in technological terms (hard sciences), or in humanistic-epistemological terms (social sciences). Advanced research, education, communication, learning will be the key words representing the contents of the virtual heritage and will constitute a relevant social impact for the future communities.

The recent advances in 3D data acquisition and modeling enabled the digitization of archeological subjects like buildings or whole sites. Through extention of these techniques by customized modern data processing and visualization technology, the digital cultural heritage is successfully being made accessible for the scientific community as well as for the wider public. Nevertheless, the gigantic amounts of acquired and generated data representing the digitized archeological artefacts still render the problem of visualizing, interaction with and access to them a challenging one. Recently, great advantages in the area of 3D scanning and modeling for the acquisition of archeological 3D models and buildings were made. Tools for the post-processing, data representation, and rendering for the detailed interactive display and inspection of such models even on low cost platforms will be available in the near future. In addition, different 3D Multimedia tools for the presentation and navigation in high-quality digital model collections are in the focus of current research and development activities.

In recent years great efforts were undertaken to acquire, store, distribute and visualize archaeological objects and whole excavation cites. Past efforts for integrating Cultural Heritage content within a computer-based rich media framework have fallen in either one of two categories, each of which has its own methodologies and techniques, which have made tremendous progress independent from each other over the last years: 3D capturing: many semi-automatic methodologies and devices have been proposed to reconstruct 3D models from existing scenes/artefacts (range scanning, photogrammetry, shape from video, etc.); synthetic reconstruction: 3D modelling from scratch, based on incomplete data such as floor/ground plans, stylistic information and educated guessing. The models produced are based on a logical organization and more synthetic

(modelling by feature or components); on the other hand, metrical accuracy is often unknown and depends heavily on the operator cleverness.

Starting from these premises the next efforts have to be addressed towards an integrated approach, with the possibility to use all the spatial technologies available for the survey, the monitoring and the reconstruction of an archaeological site or landscape: everything in 3D with an excellent accuracy of the whole process.

A key issue of the archaeological research is the reconstruction of the past throughout highly destructive activities, such as the excavations, and not destructive landscape investigations by topographic survey, remote sensing and digital technologies. Both these activities, intra-site and inter-sites, create a huge amount of information of difficult accessibility because of different archives, platforms, acquisition methods, standards, type of data, etc. Because of the very long process to elaborate this set of information, unfortunately, most part of the archaeological investigations are unpublished and, if published, the dissemination is, more or less, related to the scientific community, with a minimum social impact and few perspectives of didactic communication. Furthermore, this long process of complex and articulated knowledge is documented only in the archaeologist's mind and it is not transparent or accessible after the final interpretation. So, doubts, hypotheses, theses, predictive models, comparison with different models, don't appear in a final scientific report, not showing a so fundamental phase of dialectic interaction with the archaeological information and progressive knowledge of the past. On the contrary, the human process of learning and cultural transmission is made by a cybernetic difference between us and the environment we explore (see for example, G.Bateson, Ecology of mind): we learn through the difference.

According to this premise we think that the construction of a spatial virtual reality system dedicated to the investigation of the ancient Urkesh can constitute the beginning of a new challenge for the archaeological methodology, passing directly from the fieldwork to the virtual reality, from the scientific domain to a collective communication, keeping all the data within the same interactive environment. This ambitious result can be obtained on the basis of a technological integrated approach collecting all the data in a VR system: GIS, remote sensed data, stratigraphies, monuments, structures, everything reconstructed and surveyed in 3D.

We plan to create a VR platform collecting the data from the site (observable intra-site landscape) and, then, constructing the reconstructive hypotheses in real time according to the 3D models registered on site.

All the 3D models could be linked with meta-data: SU (stratigraphic units), movies, drawings, pictures, DEMs, etc. In this way the users will be able to interact within the same immersive environment in real time and on low cost hardware platform.

The digital environment reconstructed will include: the observed landscape, the classified landscape, the simulated landscape, the reconstructed landscape. All the data accessible in the 3d space will be extremely accurate and detailed in scientific terms, but even comprehensible and attractive for didactic and educative aims.

"Space the place" means that it is fundamental to interpret the landscape in terms of places and collective memories; but also that we need to use spatial sciences for interpreting and communicating landscapes, artefacts, monuments, in one word for creating Virtual Heritage.

Hardware technologies: 3D Laser scanners (2-6 mm of accuracy), DGPS dual frequency with Racal system integrated (20-30 cm of accuracy); laser topographical total stations, virtual theatres.

Software technologies: ArcGIS Pro, Er Mapper, Terravista, Rapidform, Virtools, C++ libraries, Cyclone, Photomodeler, 3D Studio Max, Maya, Realnat, Autocad, Visual Basic programming.

Starting from these premises the next efforts have to be addressed towards an integrated approach, with the possibility to use all the spatial technologies available for the survey, the monitoring and the reconstruction of an archaeological site or landscape: everything in 3D with an excellent accuracy of the whole process.

Everything must be "spatial", namely all the data processing needs to integrate different digital sources of information: maps, models, cartography, remote sensed imagery, interpretations, reconstructions, and so on. An integrated approach includes different skills and technologies, in particular: DGPS, laser scanners, photogrammetry-photomodelling, GIS, remote sensing, virtual reality.

7 Remote Sensing Applications

A preliminary remote sensed analysis was undertaken in 2003 for contextualizing the archaeological area with different multispectral and spatial sources. In this preliminary phase we have used a Corona (fig.6), a Landsat ETM 8 bands (fig.7, 7 bands of 30 mt and 1 band of 15 mt. of resolution), a SPOT (fig.8, panchromatic, 15 mt of resolution).

In particular, the Corona imagery in panchromatic band, has been rectified (in 2D) using DGPS control points got on the field.

The result is interesting: it is possible to follow traces of the defence walls of Urkesh in the East, West and North side (fig.6). The border on the South side is uncertain, the

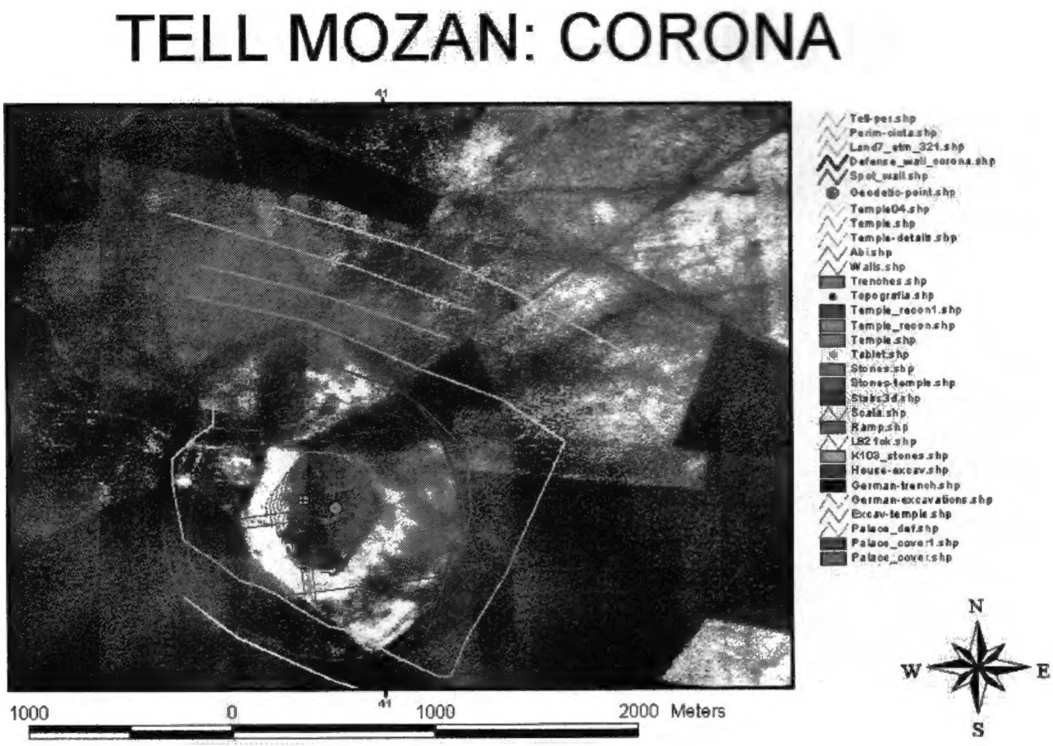

Fig. 6 Corona imagery

general shape appears ovoid and the traces are well defined (fig.6).

In the second image, a Landsat ETM 7 bands (fig.7) the situation is different: it seems that the defence wall is of quadrangular shape and wider than in the other images. In the north side there are three additional linear traces, maybe identifiable as

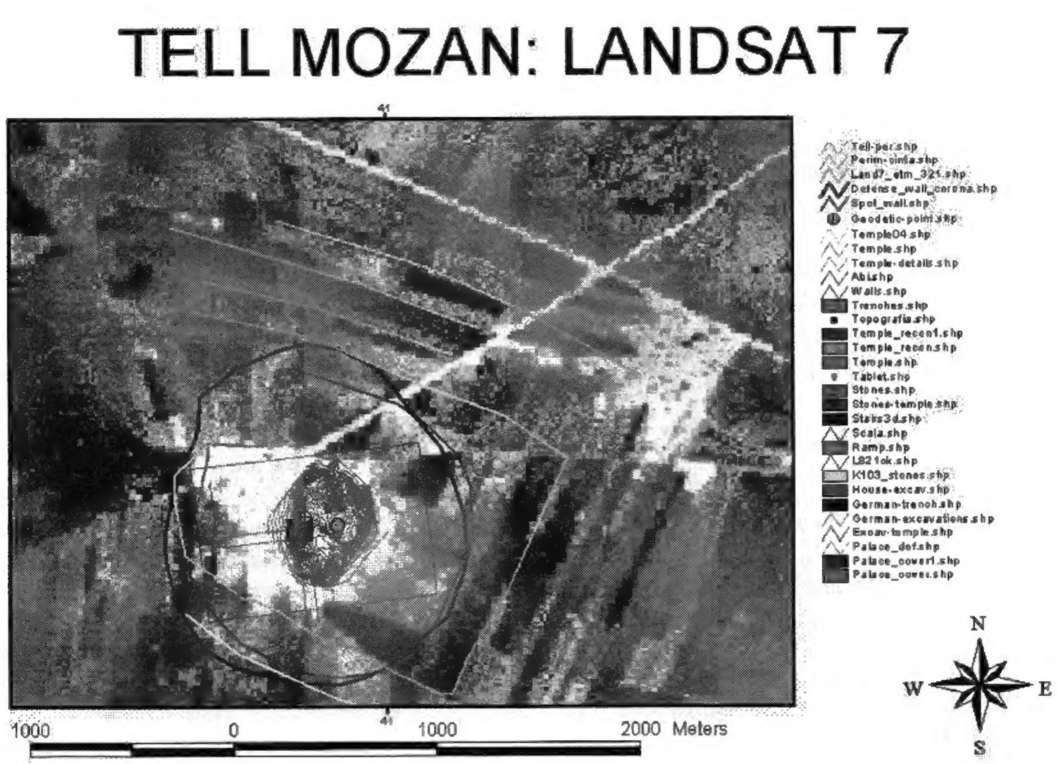

Fig. 7 Landsat 7 ETM 8 bands imagery

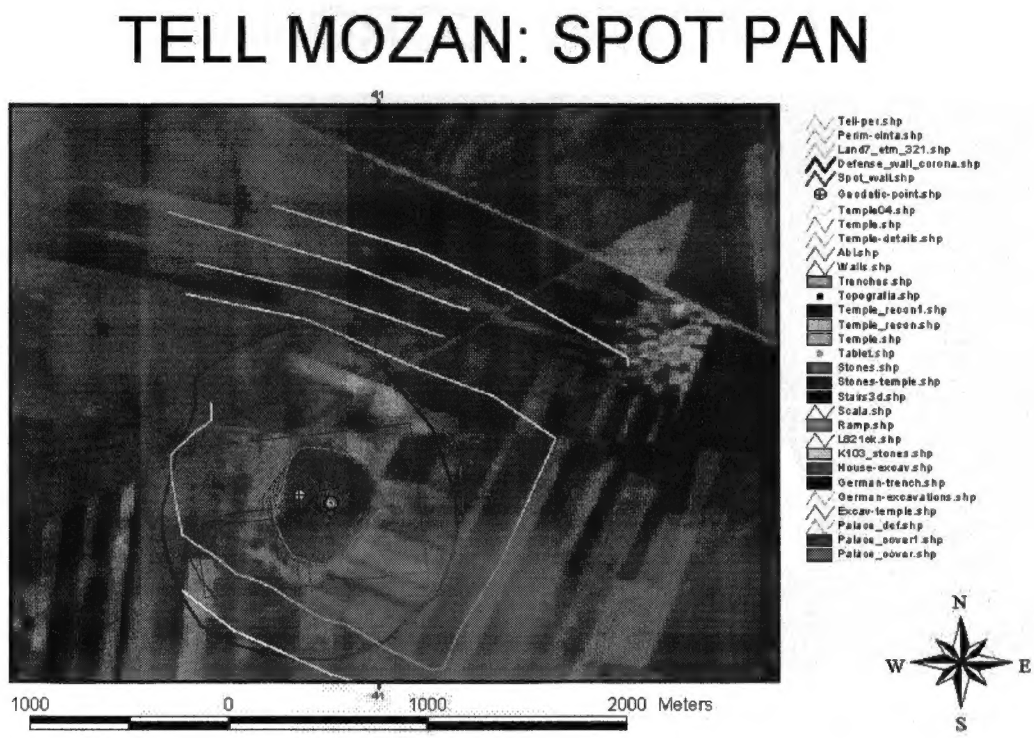

Fig. 8 SPOT Panchromatic imagery

In the third imagery, the SPOT imagery, the defense walls appear of circular shape even if it is difficult to identify the north-west side (fig.8). The different traces in the three overlays can be explained with distinct degrees of visibility and humidity of the ground (the images belong to different seasons), and of the spectral content of the satellite image.

In the SPOT imagery the light components in the gray level scale are corresponding in particular to the anthropic terrain surrounding the *tell.*

Comparing in overlay all the traces identified on the three satellite imagery, it seems that the defense wall is of circular shape with a perimeter of about 4500 meters. The other traces and anomalies identified in particular on the Landsat imagery could belong to other defense walls, maybe concerning the evolution of the settlement.

8.0 DGPS survey

During the archaeological fieldwork 2003 a systematic survey by DGPS has covered all the area with the following aims: georeferencing the archaeological excavations with centimetric precision, rectifying aerial and satellite imagery, creating detailed DEMs of the areas of the temple and of the palace, defining the training regions on the site for the supervised classifications. The DGPS is a Leica 510 single frequency integrated with a Racal system able to use the real time correction of the Landstar service. LandStar-DGPS is a satellite delivered GPS correction service providing 24 hour accurate and reliable real time precise positioning on land and in the air in over 40 countries.

With a series of reference stations throughout the world working through the company's 24 hour manned control centres, LandStar-DGPS represents the most extensive wide area DGPS network operating today.

LandStar-DGPS broadcasts DGPS correction data to users via the L-Band satellites. The system operates on a common global standard allowing LandStar receivers and those that are compatible to operate on any of the LandStar networks world-wide.

Corrections are derived from a wide-area network solution, assuring LandStar users of a robust and highly redundant service. This allows real-time positioning accuracies of one metre or less to be achieved throughout the LandStar coverage areas.

With this system it is possible to have an accuracy of 20-25 cm in real time and in kinematic way; otherwise with a static method it is possible to reach about 10 cm of accuracy in 30-40 minutes. The system works on a Bluetooth PDA and it is integrated in Arcpad, so that it is possible to follow all the processing in real time, upgrading the archives day by day.

In particular the DEM corresponding to the area of the temple has enhanced several micro traces mainly in the southern side (fig.5). The presence of these evident traces

can suggest a wide monumentalization in the area of the temple, maybe for isolating and emphasizing the sacred building.

9 Virtual Reconstruction of the Archaeological Landscape

Knowledge and diachronic interpretation of an archaeological landscape depends on factors of perception, self-referring, interaction ("feedback") and cultural learning. Therefore for interpreting the landscape we have to create the "map" in batesonian sense ("The map is not the territory"), the map is the virtuality, the "difference", the territory is the reality.

In theoretical sense we distinguish three levels of landscape to investigate and to interpret: mapscape (virtual landscape by GIS and spatial data), taskscape (activities and relations of the landscape), mindscape (perceived landscape, digital ecosystem).

In conclusion, we will face up methodological and technological problems of the virtual reconstruction using OpenGl software and libraries in order to project, to reconstruct and to navigate the ancient landscape in real time. The new rules of this digital ecosystem will be autopoietic, in the sense that they follow ecological and cyber-anthropological theories. Each interaction in real time within the virtual landscape will produce difference and, through the difference, new ways of learning.

10 Photo Modeling Tecniques at Urkesh

During the archaeological campaign 2003 in Tell Mozan, because of the numberless presence of manufactures and architectures, found in more than 20 years of excavations, we decided to test techniques of photo modelling to document a part of these archaeological presences, with 3d metric models.

Photo-modelling is a technique which permits to extrapolate from every different kind of photographic material, sizes and three-dimensional models. Using a camera like input instrument, this technique permits to calculate measure and construct existing structures or objects. After the acquisition of one or more pictures of the object that has to be reconstructed, the operator marks the interested points directly on the images and decides contingently bonds and correspondences. Afterwards the software processes the pictures and detects the points inside the Cartesian space, constructing the 3d model.

A 3d model, created with this technique, is composed by a series of points, lines, edges, curves, surfaces and cylinders, connected each other to represent an object; all these elements have an X,Y,Z value, and are projected in a virtual space.

One of the best advantages of this technique is the possibility to construct simple or complex models according to the needs of the operator. To test this new technique we used PhotoModeler 5.0, this software, created by Eos systems, is used to model and measure throughout many industry sectors such as accidents reconstructions, architectures end preservations, films, videos and animations, forensics, plants and mechanical engineering.

The creation process of a 3d model, can be synthesized in six passages: camera calibration; planning of the photographic click and markers position; acquisition of the pictures; identification of equivalent points; elaboration of the dates; export of 3d information.

To acquire and elaborate the images, the software needs a detailed description of the camera; in this way it is possible to construct a correct relation between the points on the pictures and the points plotted in the Cartesian axes. This description includes information about the lens distortion, the focal lens and the image scale. The process of calibration is executed only one time and its parameters can be used for all the projects, but it is necessary to execute a new calibration process for every new camera.

11 Digital Processing

Before of the acquisition of the pictures, it is very important to observe with attention the architecture of the monument and its position in the landscape; actually, pictures can't be taken in a properly way if the distance between the camera and the object itself is too small. There isn't a determined rule about the creation of marks: the best solution is creating every time a specific marker for the monument to acquire.

Until now we have elaborated three different kind of marks: adhesive marks (that are generally used on hollow or convex surfaces; they have a circular shape and a very short size (ray of 5mm), plasticine marks (these markers are modelled like little spheres and are generally applied in the corners of the monuments) and the stake marks (the stakes are generally put around the monument as control points).

To obtain good pictures it is necessary to follow some rules: first of all, it is very important to try to have angles near 90 degrees between the pictures; in fact, if the angle is far from that value the points accuracy is worse. Another useful expedient consists to try to include all the necessary points in at least three pictures. Moreover, it can be very useful to take pictures from different heights. To acquire good pictures it is also very important to use a good digital camera with at least 4Mpixels.

Thanks to all these information the software is ready to determinate the points position in the space.

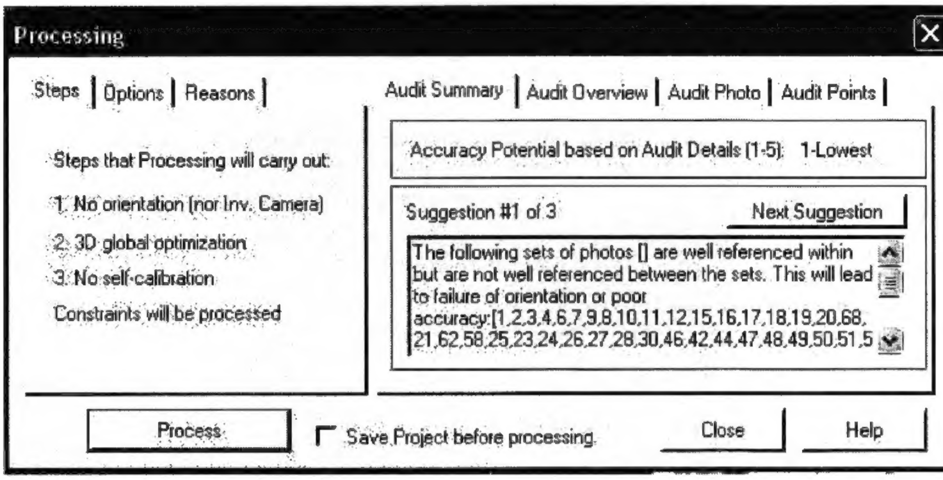

Fig. 9 This image shows the steps of the processing

Once completed the referencing phase, it is possible to process the data, and if the accuracy is acceptable, the software will elaborate a model. During this step the software, through a dialog window, provides information about the imported data and about the level of accuracy of the points. Moreover, the software gives a series of advices to improve the precision of the model.

After the creation of a 3d model it is possible to export it in other formats: DXF, 3DS,OBJ, VRML, IGES, ROW.

The DXF format is supported by every 3d program, but this format don't permit to export textures and materials, while the format files like 3DS, OBJ, X, VRML1 and 2 give the possibility to manage materials and textures. Finally the ROW format permits to export a table with the coordinates relative to the 3d model.

Our models were imported in 3d studio max 6 and modified according to the aims of the project; usually, we set up new materials or create missing part of the monument, especially when (for space problems) it is impossible to take pictures. To import in 3dstudio max a model created with this technique, it is possible to export it in two different formats: VRML and 3DS. The first one permits to import also 3d line edges and curves, while to visualize the second format (3DS) in a correct way it is necessary (after the importation) to apply a mesh modifier; moreover, this last format export only surfaces and cylinders.

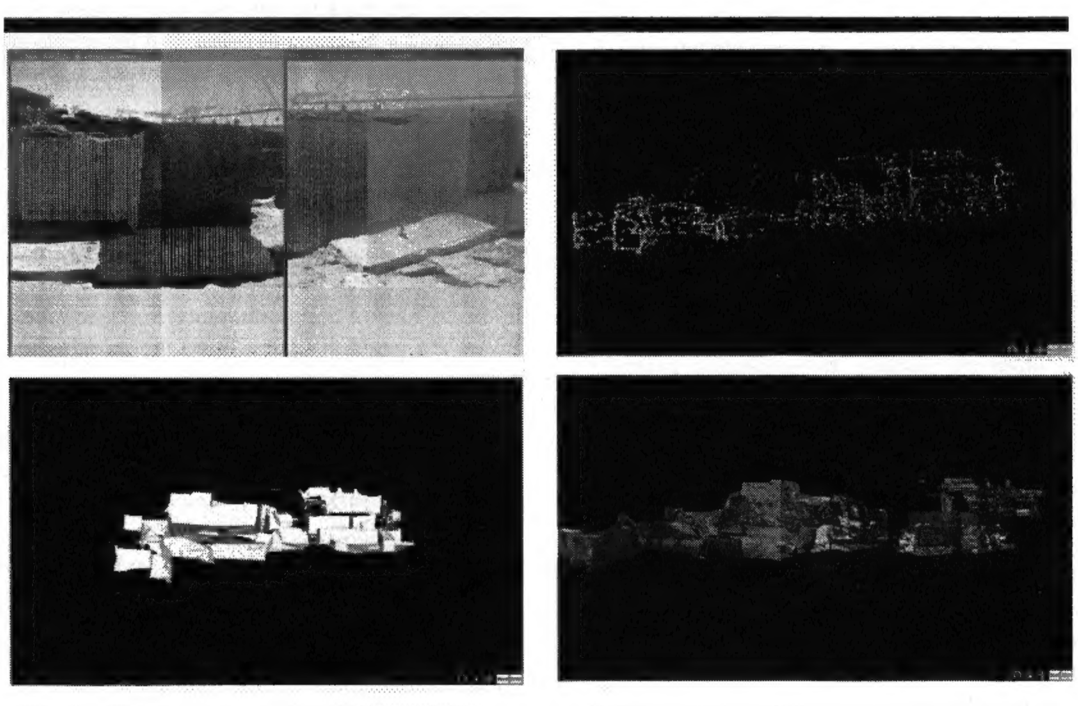

Fig. 10 These images show the different steps of the palace reconstruction, from the referencing to the application of the textures.

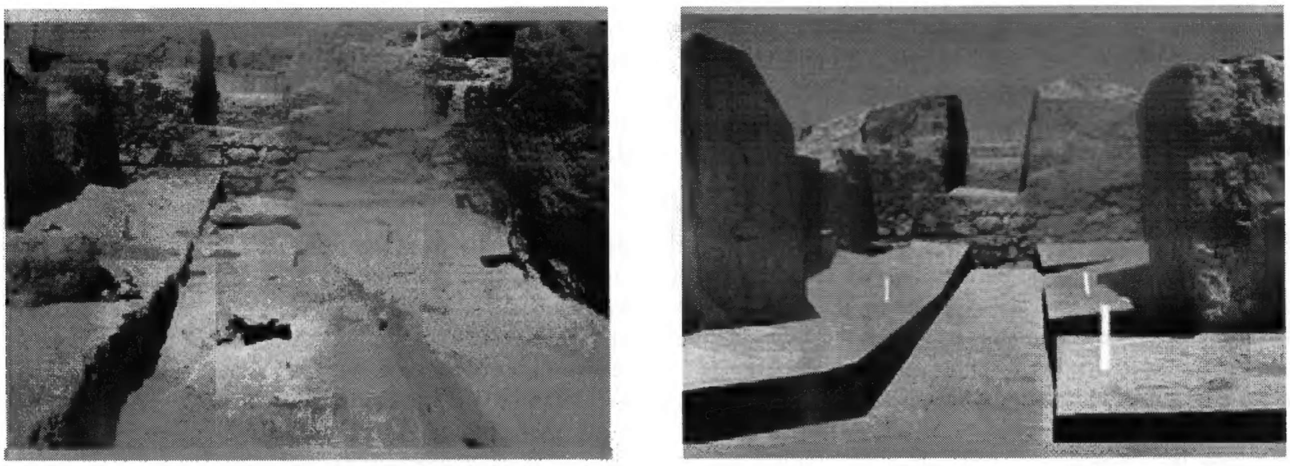

Fig. 11 This image shows a picture of the room C5 of the palace and a snapshot of the 3d model of the same room.

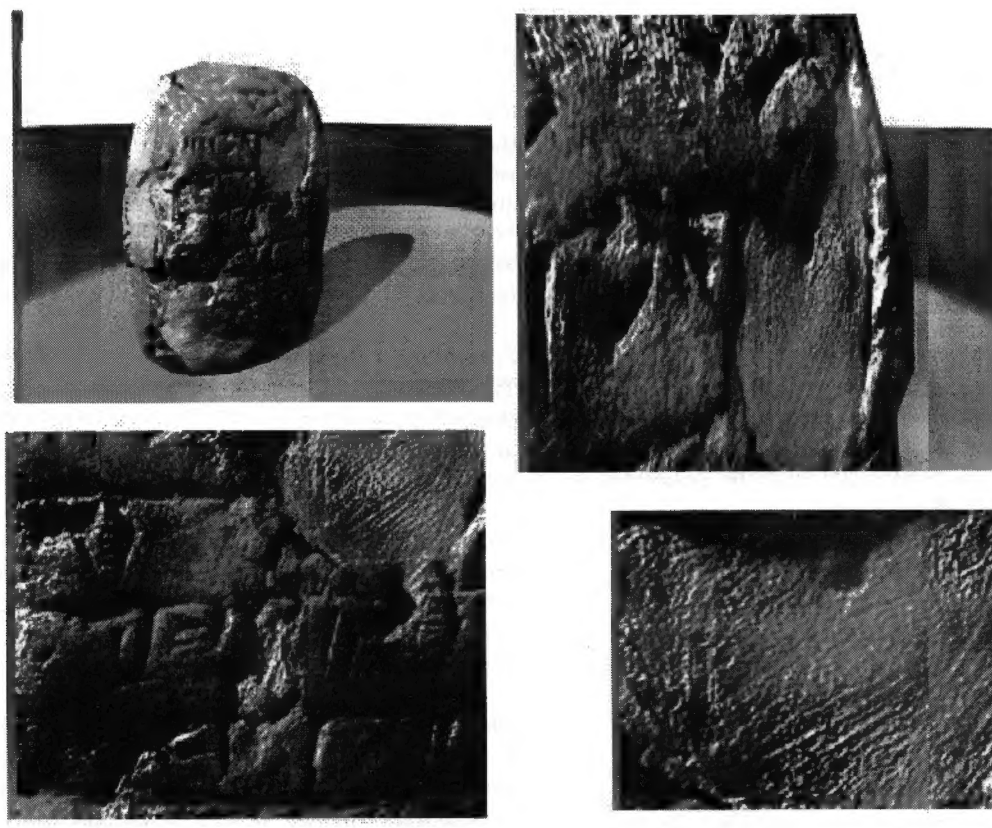

Fig. 12 These images show the 3d model of the tablet, and some of its particulars.

12 Case studies

To test the real potentialities of this technique, we tried to apply it in two different cases: the royal palace and a Urrian tablet. We have chosen these two different examples to test the technique in a micro and a macro scale context.

The palace, actually object of the excavations, belonged to the Urrian culture since 2700 b.C. It is composed by many different connected rooms and the area, chosen for the research, is approximately of 480 square meters. For this project we used a Nikon Coolpix 9900 with a wide angle and mobile screen, with a resolution of 4 megapixels. Anyway, we had some trouble with the acquisition of the pictures: a) the space around the walls was too straight to take pictures, b) the walls had different heights, so it was very difficult to take panoramic shots of the single rooms.

At the end of the photographic campain and of the elaboration of the data, we obtained a 3d metric model, composed by 1892 polygons and 5004 vertexes, completed with orthorectified textures (fig.10). The accuracy of the model, after the process of photo-modelling, is of two centimeters.

Finally, exporting the model in 3dsmax 6, we have reconstructed the missing parts of the palace (fig.11). We also have tried to apply photo-modeling techniques to an Urrian tablet, nine centimeters of height; this manufacture has an inscription upon three of its six surfaces, which describes commercial transactions.

We took the pictures in a room equipped with artificial lights and special photographic tripods; these factors contribute to have optimal conditions during the acquisition of the photographic material. For the tablet we used a different camera: the Nikon D100 with 6Mpix. The high resolution of the images taken with this instrument permitted to create a very detailed 3d model, composed by 1416 vertexes and 472 polygons (fig.12). Moreover, the high definition of the textures concurred to observe in detail the object's material.

It was possible to construct this second model in only four hours. Moreover, the high quality of the pictures permitted to obtain measures very close to the reality (the object and its virtual model differ only two millimeters).

All the models created with this technique will be used to populate a virtual archaeological landscape where every object, structure, or hand made, will be connected to multimedia archives and metadata.

13 Conclusions

The project is still in progress but we are defining the general methodology in order to plan the next field activities based on integrated technologies.

A key issue of the archaeological research is the reconstruction of the past throughout highly destructive activities, such as excavations, and not destructive landscape investigations like topographic surveys, remote sensing applications and digital technologies. All these activities, intra-site and inter-sites, create a huge amount of information of difficult accessibility because of different archives, platforms, acquisition methods, standards, type of data, etc.

In addition, in many cases the remote sensing applications are not integrated in the process of reconstruction of the archaeological landscape, and they represent a separated domain. According to this perspective the need of a new digital protocol for the landscape reconstruction constitutes a first step for integrating different methodological approaches in a unique spatial environment of virtual representation and exploration.

In fact, the construction of a spatial virtual reality system dedicated to the investigation of the ancient and archaeological landscape can constitute the beginning of a new challenge for the archaeological methodology, passing directly from the fieldwork to the virtual reality, from the scientific domain to a collective communication, keeping all the data within the same interactive environment. This ambitious result can be obtained on the basis of a technological integrated approach collecting all the data in a VR system: GIS, remote sensed and spatial data, monuments, structures, mental maps, everything reconstructed and surveyed in 3D.

Therefore, a VR platform can collect data from the site (observable intra-site landscape) and, then, construct the reconstructive hypotheses in real time according to the 3D models registered on site. All the 3D models can be linked with meta-data: SU (stratigraphic units), movies, drawings, pictures, DEMs, etc. The challenge is to transform a virtual landscape in an open space of digital self-organised behaviours (active and passive) explored and queried by the user/navigator.

Possible development of the system and remarkable features.

Portability of the system
The final viewer can be installed on PCs equipped with powerful graphic cards (128-256-512 mb) without need to install specific software. The interaction and accessibility will be free.

VR desktop
Desktop virtual reality means that the system runs on low cost PCs and workstation; this kind of equipment can be easily available for museums, cultural institutions, schools, universities and the scientific community.

Timeline
A timeline representing the evolution of the site and of the environment permits to visualise all the main chronological phases of the landscape from different perspectives.

3D
All the older and newer data coming from the archaeological excavations, archaeological landscape and topographic survey are processed and visualized in 3D.

3D immersive behaviours
All the interactions and actions are within a 3D environment. Preview actions: flythrough, walkthrough, editing and movement of 3D objects, queries, multiple texturing, transparency of structures, browsing and slicing of stratigraphic units, representation of volumes and surfaces including even stratigraphies and soils.

Spatial georeferenced environment
All the data, models and behaviours can be interacted and visualised in a spatial and georeferenced 3D environment, so that every scientific processing is done according to high quality and accuracy of the data.

Cultural and methodological contextualization
This system overlaps old archives and newer acquisitions in a unique frame and cultural context of information.

Data standardization
All the spatial data coming from GIS and remote sensing platforms, from excavation maps and old archives, originally in different format (.tif, .img, .jpg, .shp, .ecw, .ers, .alg, .dwg, .dxf, .apr, geodbase, .hdr, .3ds, .flt, .vrml, .tin, .grd, ascii, ecc.), are standardized for a general overlapping and compatibility in the same environment.

Simulation
The artificial environment of virtual reality becomes the ideal territory for activities of simulation of events and predictive modelling, even with the use of genetic algorithms.

Multimedia
The virtual environment hosts different multimedia sources such as movies, pictures, drawings, models, everything within an inclusive space.

Upgradeability
Year by year the system will can be upgraded with new data and information. In the near future it is possible to plan a Web version of the same system based on Virtools web player or open source software.

Scientific communication and edutaiment
The portability and user friendly interface of the system can be fit for scientific and educational aims in the same time.

Fast time of data dissemination
The passage from the fieldwork to a virtual reality system of spatial data avoids the long and unfinished process of printed publications of archaeological excavations.

Accessibility of heterogeneous data in the same environment
Multiple sources of information coming from excavation and from landscape survey can be visualised in the same 3D space.

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